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METHANE RECOVERY/UTILIZATION - CASE HISTORIES

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ABSTRACT

Two cases of methane recovery and utilization are presented.   In one case, the
source is from unminable coal seams with recovery of the methane effected through a
vertical well in which coal formations have been hydraulically stimulated.   In the
second case, the source of methane is a horizontal **borehole** degasification program
in the Pittsburgh seam at an active coal mining operation.   In both cases all
recovered methane is used on site as an auxiliary **energy source.** Brief economic
evaluations are presented for each case.

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1.0 CONTRACT DE-AC-21-78MC08332

This program is underway at a Westinghouse owned 850 acre site in Westmoreland County, Pennsylvania. Adjacent mining activity was discontinued about twenty years ago due to the relatively poor nature of the coal on site. Within the 850 acre site, four individual sites have been cored, two of these sites have been drill stem tested, and one of the four sites has been developed to a gas producing well. The methane flow from this well is collected through an underground pipeline system which feeds the gas to an on-site Westinghouse industrial operation. The gas is used as fuel for gas fired industrial process heat boilers on-site. The coalbed gas is of high quality with a heating value in excess of 1000 BTU/ft^3. This fuel requires no additional processing beyond the wellhead and is mixed directly with commercial pipeline gas fed into the site by commercial suppliers.

Figure 1-1 shows an aerial photograph of the 850 acre site, and Figure 1-2 shows the production well as it exists today. Figure 1-3 shows the occurrence of coal formations down to 750 feet of overburden, and the division of these formations into zones for hydraulic stimulation. Table 1-1 summarizes the stimulation procedure used.

Resource evaluation and reservoir characteristics 1 for this site show an in-place gas content of 7960 MCF/ACRE with 60% recovery if the site is developed properly. Present planning for initial development of the site is based on a six well system, with 40 acre spacing, over the western portion of the 850 acre site. Producibility is projected1 to average 300,000 SCF/Day from the six well system over the next ten years.

Figures 1-4 and 1-5 summarize the actual performance of the one gas producing well on-site. Total production by this well, all of which has been consumed on site, has exceeded six and one-half million cubic feet At the present price (3.23/mcf) of commercially supplied natural gas, this represents a site energy cost reduction of $22,000.

The smooth curve shown in Figure 1-4 represents the projected (open'hole) flow based on a computerized two phase flow model developed by INTERCOMP Resources. The remaining curve in Figure 1-4 shows actual (closed system) daily flows as measured at the wellhead. Figure 1-5 provides a comparison of site gas needs and gas produced from the methane production well. As indicated, the well provided up to 100% of the local Westinghouse gas needs for brief periods.

2.0 WESTMORELAND COUNTY SITE ECONOMICS

Westinghouse usage of commercially supplied natural gas varies throughout the year at this site. There is normally a peak usage period early in the year and a reduced rate of usage in the summer months. Overall the site now requires approximately 75 x 106 cubic feet of commercially supplied natural gas annually. This data is based on 1978-1979 history of gas usage at the site, and total annual usage now is somewhat lower than in earlier years when it was about 100 x 10^6 cubic feet. In either case, the projected production of the six well coalbed methane system, at 300 MCF/Day, exceeds the local demand during parts of the year. This will require 'either modulation of the fuel flow system or finding another local use for the excess. If this excess is sold to the commercial pipeline (which is already located on site) the value of the gas, at the current "field price", is only about $1.65/ 103 cubic feet. On the other hand, with some modulation of the system to better

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1. Completed by INTERCOMP Resources, of Houston, Texas.

Figure 1-1. Aerial View of Site at 12,000 Feet
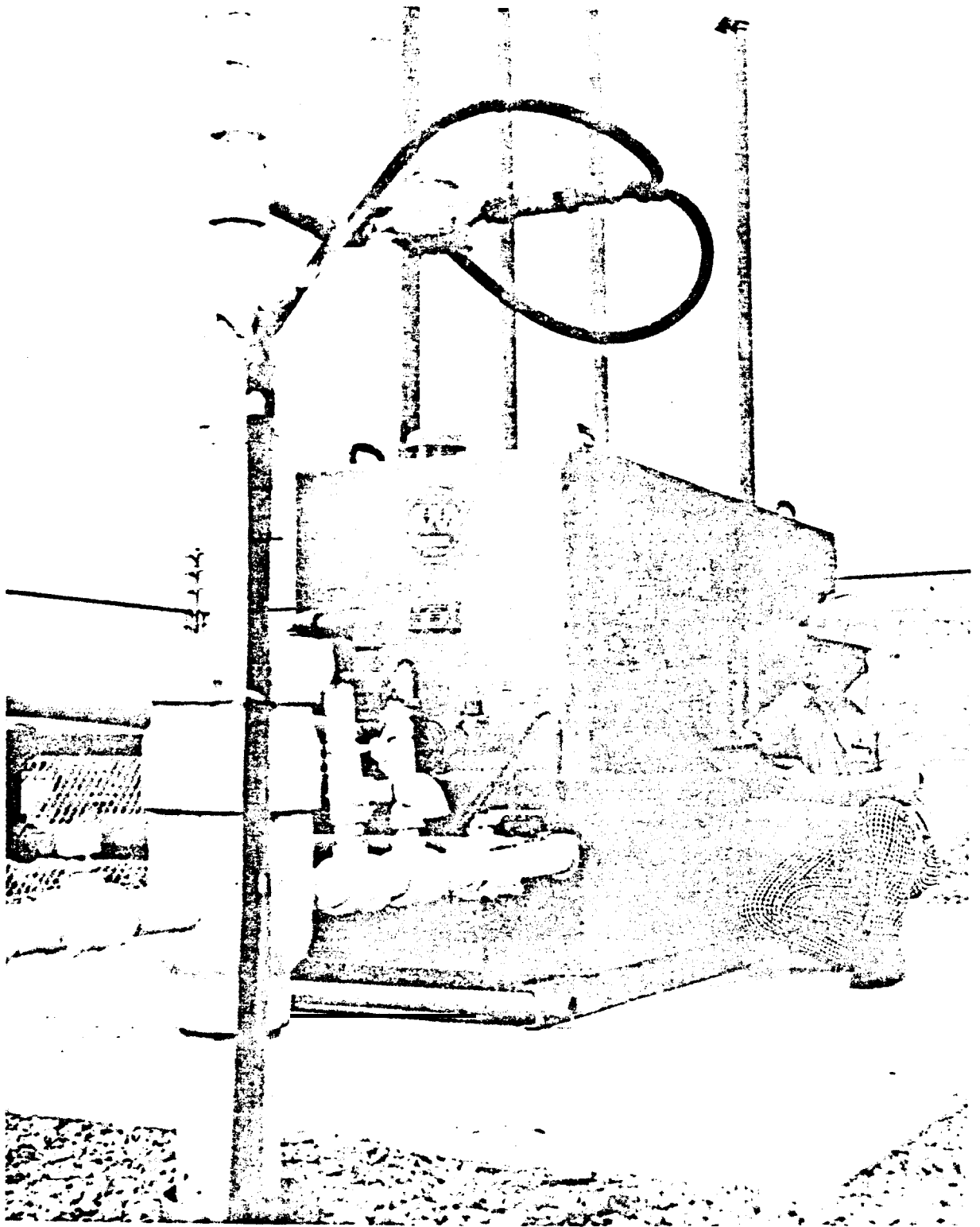
Figure 1-2. Production Well

EACH ZONE TO RECEIVE:

● 5 STAGE FRACTURE
  TREATMENT

● EACH STAGE INCLUDES:
  - 430 BBL WATER AND
    6720 LB OF SAND

TOTAL VOLUMES USED FOR
ALL ZONES:

● 6475 BBC WATER

● 76,000 LB SAND

ZONE 1 {
ZONE 2
ZONE 3
ZONE 4 {

UPPER FREEPORT
LOWER FREEPORT
UPPER KITTANNING
MIDDLE KITTANNING

CLARION

BROOKVILLE

UPPER MERCER

MIDDLE MERCER

LOWER MERCER
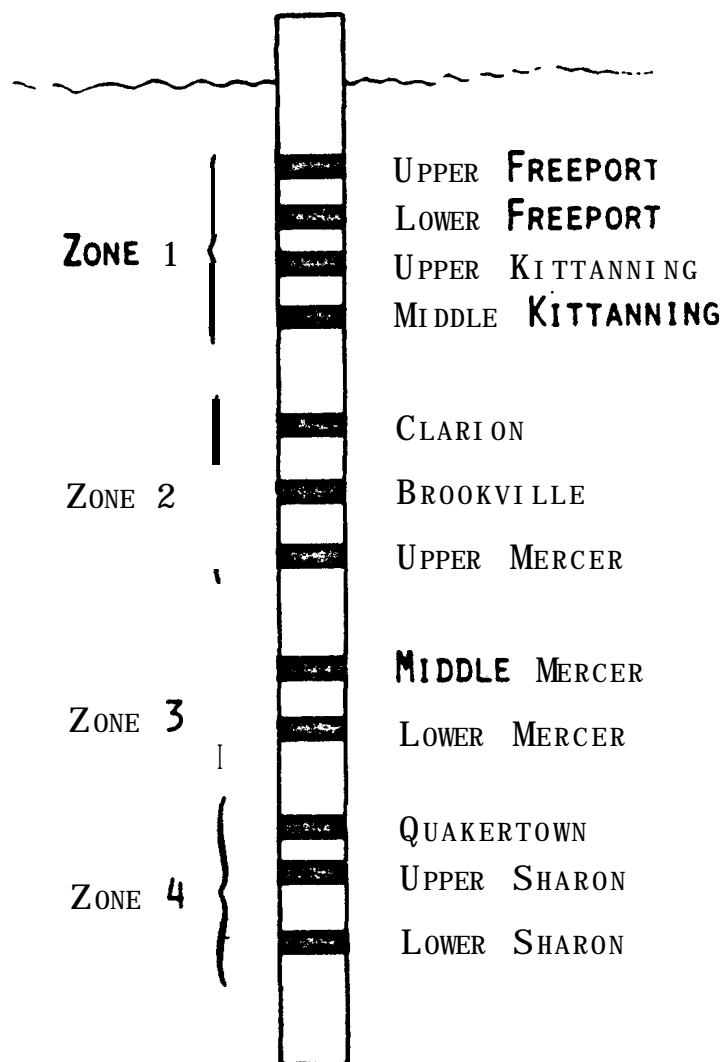
QUAKERTOWN
UPPER SHARON

LOWER SHARON

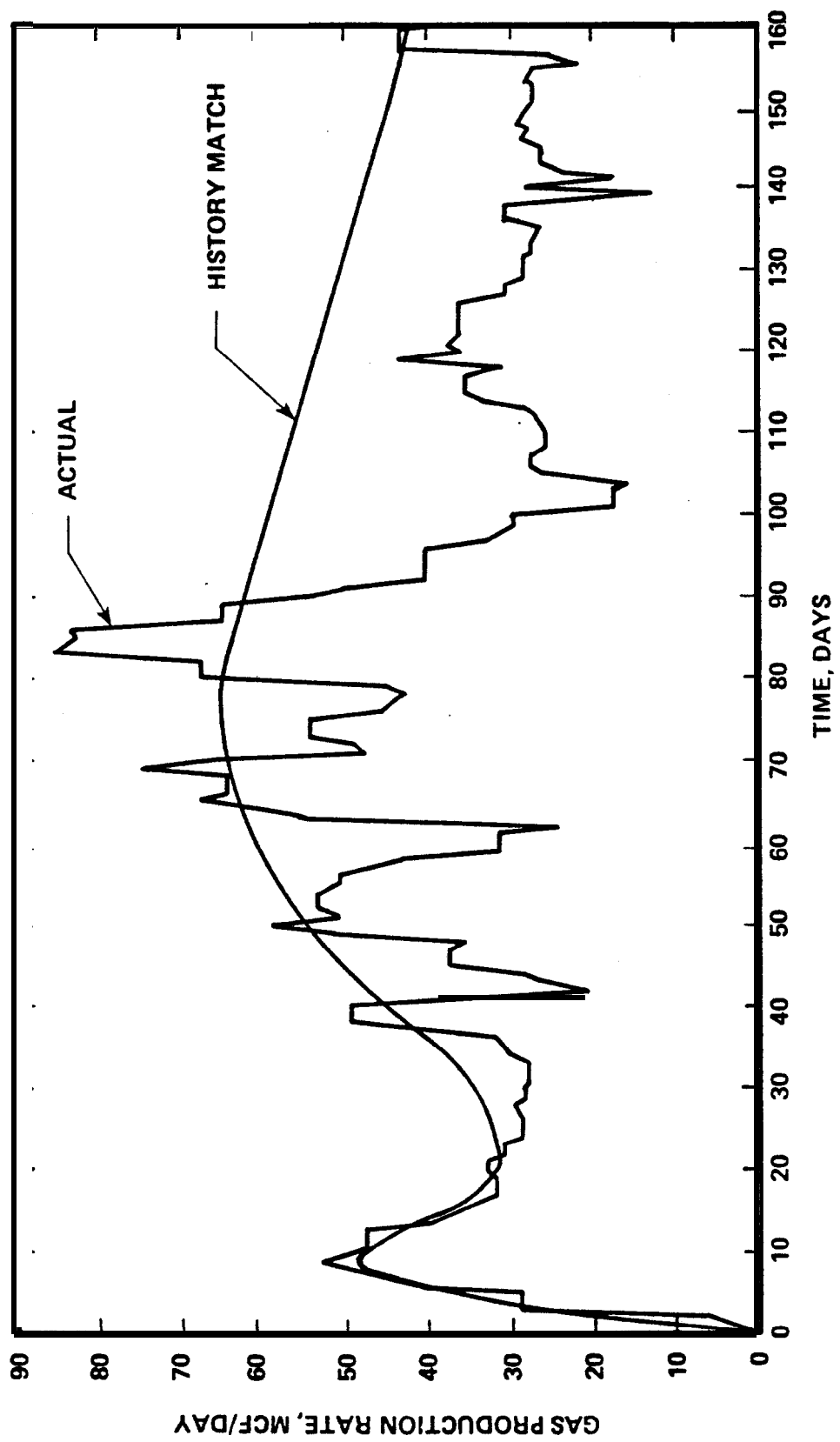Figure 1-3. Coal Formations and Stimulation Zones

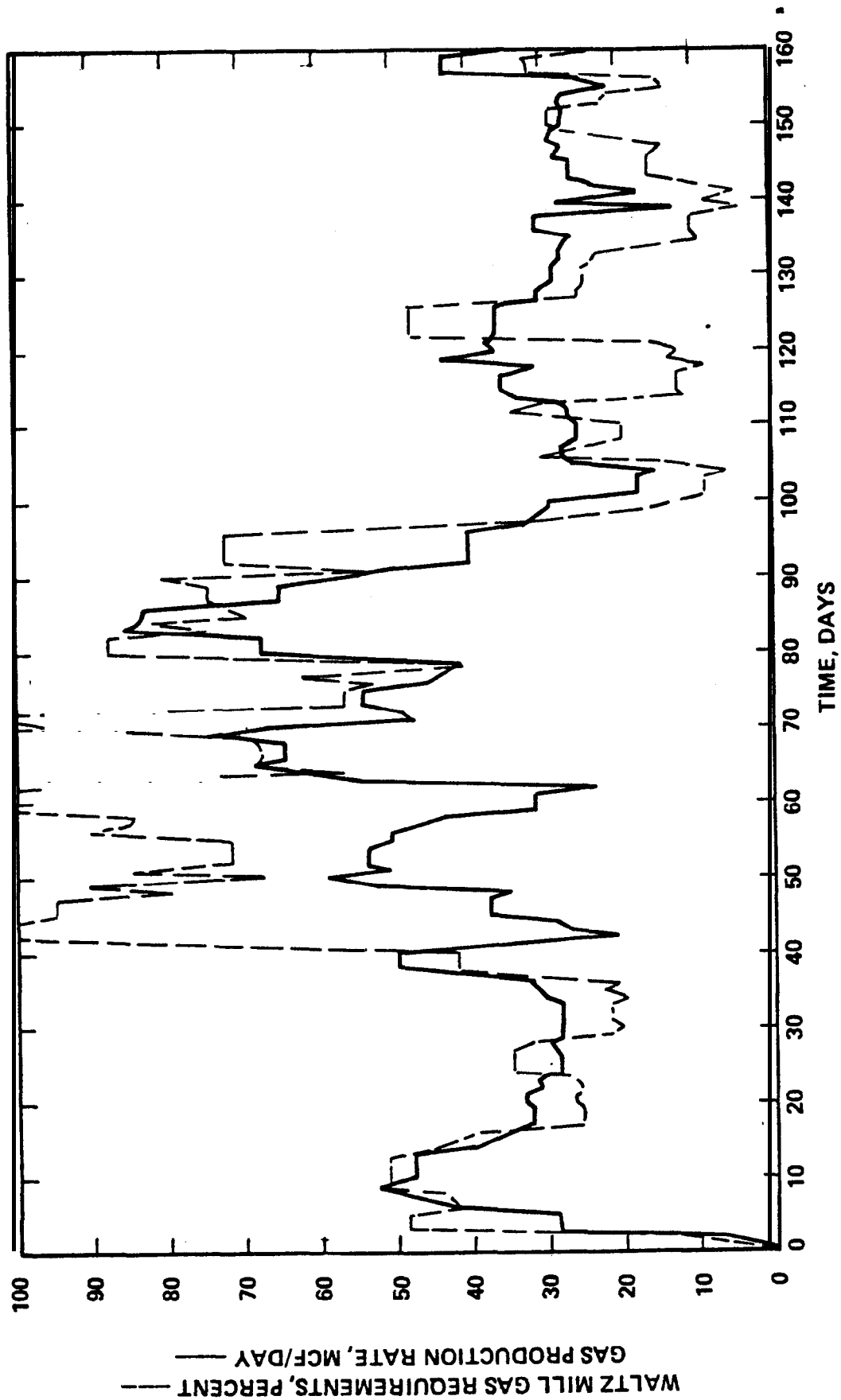Figure 1-4. Production History Simulation

Figure 1-5. Well Performance

match the energy demand **characteristic** of the site, a **higher** value can be placed on **the** gas, i.e. the present commercial rate is $3.23/10^3$ cubic feet for gas supplied to this site.

As a background data base for an evaluation of the economic viability of the system, then, the following apply:

- System lifetime is taken as ten years and average production is 300 **MCF/Day** from the six well system.

- Individual gas well flows can be reduced[2] during periods of minimum site needs.

- Site gas needs are initially assumed to'be 75×10^6 cubic feet/year, and escalate at 3.5×10^6 cubic feet/year through the ten year system lifetime.

- The initial value of the **coalbed** gas in $3.23/10^6$ BTU, and this value escalates at **8%/year.**

- Based on experience to date at **this** site, the capital requirement for the six well system is $831,000. The Operation and Maintenance cost for the system is **$0.20/10^6** BTU, and escalates at **6%/year.** Some breakdown of these costs is shown in Table 2-1.

TABLE 2-1:   COST BREAKDOWN

Cost Element	Amount ($)	$/10^6$ BTU*
Six Wells	720,000	0.79
Wellhead Equipment	60,000	.07
Collection **(Pipeline)System**	51,000	.06
Sub-Total	831,000	.92
Average 0 & M*		.28
Total		1.20

*Over a ten year system life

Under the economic constraints noted above, economic viability of the system can be estimated[3] from:

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2.   Hydraulically stimulated coal formations of this site produce both gas and water from the coal. Gas flow can be reduced by deliberately allowing the water level in the well to build up; i.e., by controlling water flow,

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3.   Analysis for Production Management, E. H. Bowman and R. B. Fetter, School of Industrial Management, **Massachesetts** Institute of Technology. Irwin Series in Industrial Engineering and Management, R. D. Irwin, Inc., Homewood, Il., 1957.

$$(2.1) \qquad S_{pw} = \int_0^T \left[\text{Ne-t Cash Flow} \right] e^{-it} dt + S_v - I$$

where

S_{pw} = present worth

T = ten years maximum

Net Cash Flow = a function Q(t) which describes the difference between gross revenues and O&M over the ten year life.

i = rate of interest

S_v = system salvage value (here assumed to be zero).

I = investment (here considered fixed at $831,000).

Under these conditions the model (2.1) maximizes the value of i when the factor S_{pw} goes to zero. For the constraints noted above this maximum value is 38.5% excluding any interest costs on the investment or depreciation costs. The system payback period is between four and five years.

If the additional constraints are imposed requiring a maximum payback period of five years and a 12% cost for investment capital, the maximum value of i is reduced to 21%, approximately.

3.0 CONTRACT DE-AC05-77ET13133

This program differs from the Westmoreland County system discussed above in two major areas:

● End use of the methane is for electrical power generation through gas turbine-generator conversion.

● The source of methane is an active coal mine in the Pittsburgh seam, in which the methane is being recovered from a horizontal borehole degas-ification program directly from face areas underground.

For present purposes, the system is presented in terms of (a) safety considerations, (b) the fuel source (c) system configuration/functioning and (d) economics. The history of this program goes back to late 1977, and has been previously reported.[4] It is sufficient here to point out that the program has experienced substantial delay, due to what have been primarily non-technical reasons, and the present site for the activity is an alternate site.

3.1 SAFETY

Safety considerations have and will continue to receive the highest priority in the design and operation of systems such as this. Although the principles of operation

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4. Proceedings of the 1st (1978) and 2nd (1979) Annual Methane Recovery from Coalbeds Symposium", DOE, Morgantown, West Virginia.

for the equipment are theoretically not new, the assembled and operating equipment does, in fact, represent a "new system" for an operating coal mine in this country. Figure 3-1 summarizes the multiplicity of agencies involved and the instrumentation requirements which have been built into the operating procedures for the system. These procedures will be further refined during the actual operation of the equipment, which is expected to be underway shortly.

3.2 THE FUEL SOURCE

Approximately two years ago the United States Bureau of Mines and Bethlehem Mines Corporation jointly developed an underground horizontal hole degasification program at Bethlehem's Marianna No. 58 Mine, near Washington, Pennsylvania. This mine is operating in the Pittsburgh coal seam. The coal characteristics, geology, design of the degasification system, and performance to date have been previously reported.[5] In brief the underground system includes four horizontal, three inch holes, drilled into the coal seam. The gas flow from these four holes is manifolded into an **underground pipeline** system which normally vents the gas to the atmosphere through an eight inch vertical well. The gas produced is clean, dry, and has a relatively high heating value (approximately 98% pure methane). The equivalent heat rate of this **source** of fuel, and the fuel characteristics, provide an energy source for near maximum power operation of an 800 **kW** gas turbine-generator.

3.3 POWER GENERATION SYSTEM

Figure 3-2 shows a system schematic of the **Marianna** No. 58 installation. The two major system components are the skid mounted gas compressor (Figure 3-3) and the turbine-generator (Figure 3-4). The latter is on loan to this program through an arrangement between the United States Army Corps of Engineers, Fort Belvoir, Virginia, and the Department of Energy, **Morgantown** Energy Technology Center.

From Figure 3-2, the major operating features and constraints at this site can be summarized as follows:

- The surface fuel source is the Waychoff Borehole. This **borehole** is near a farm residence, and the turbine-generator cannot be located adjacent to the **borehole** because of noise considerations.

- A 7000 ft. run of shallow buried pipeline transports gas output from the Waychoff **Borehole to** the Sabol Shaft Site where the equipment is located.

- The Sabol Shaft Site location includes an electrical power sub-station which is normally fed by the local utility company. This sub-station supplies both underground and surface based electrical loads in support of of the mining operation.

- Methane fueled turbine-generated power will be in parallel with surface electrical loads. One of these loads is a large ventilation fan, and switching circuitry provided by Bethlehem will permit continued **opera**-.tion of this fan during a utility company power outage.

- Part of the power generated by the turbine-generator system is fed back to the gas compressor where it is used to drive the gas compressor motor (electrical). Net power to the mine power grid is expected to be approximately 700 KW.

5. Influence of **Coalbed** Characteristics and Geology on Methane Drainage, G. L. Finfinger, L. J. Prosser, Jr. and J. **Cervik,** U. S. Bureau of Mines - SPE/DOE 8964, &conventional Gas-Recovery **Symposium,** May 18-20, 1980, Hilton-Gateway Center, Pittsburgh, Pennsylvania.
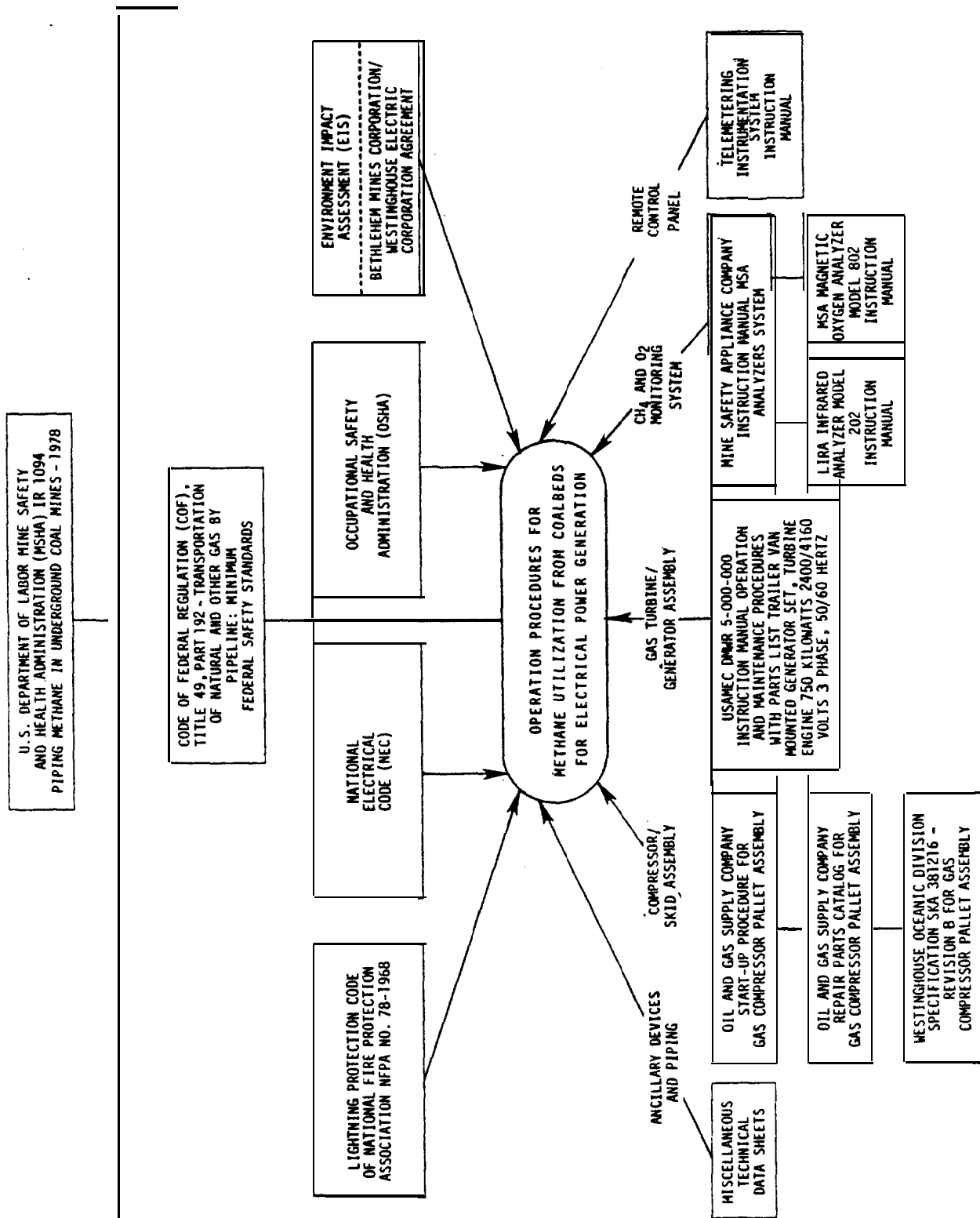
Figure 3-1. System Safety
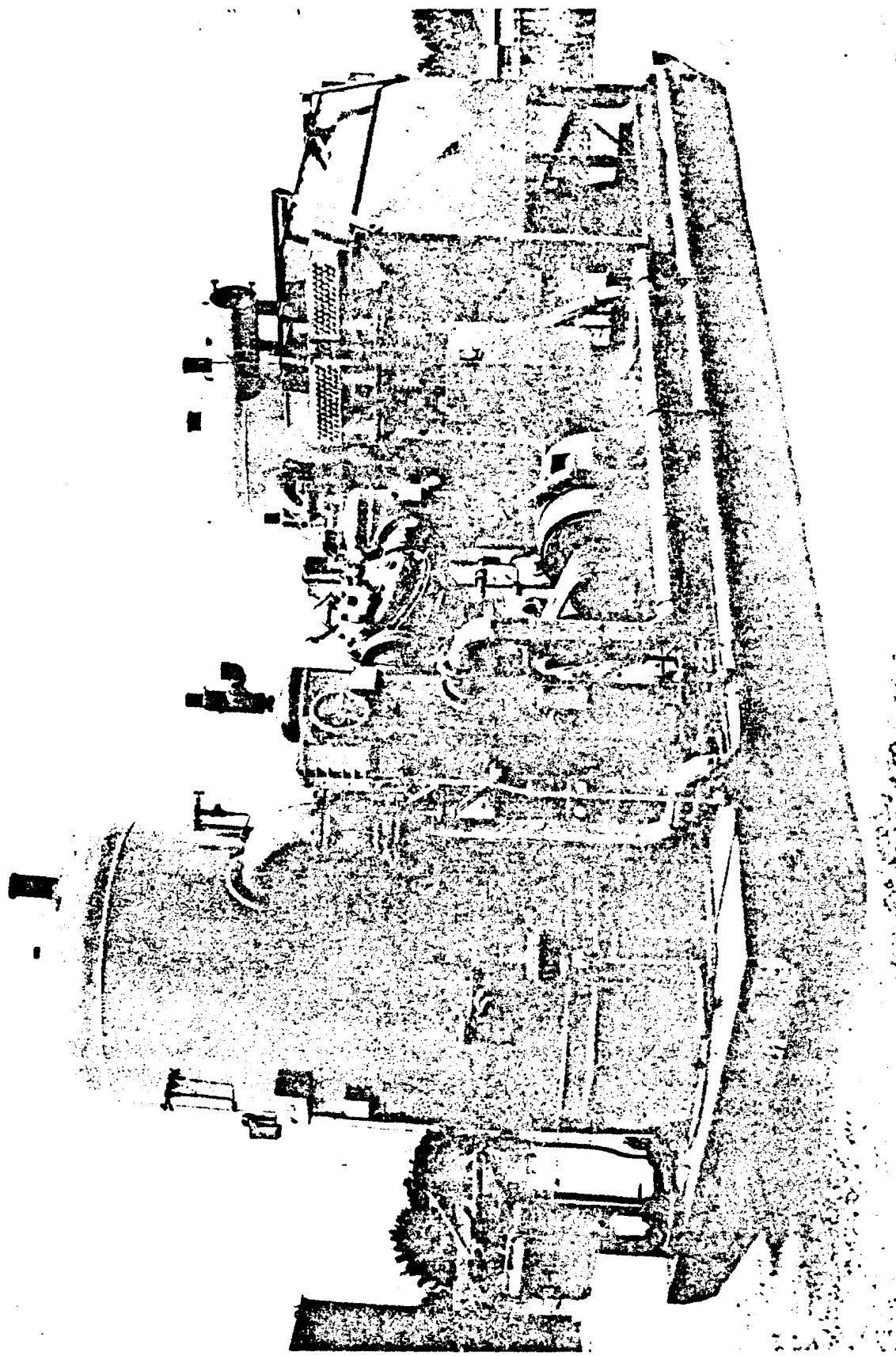
Figure 3-2. System Block Diagram

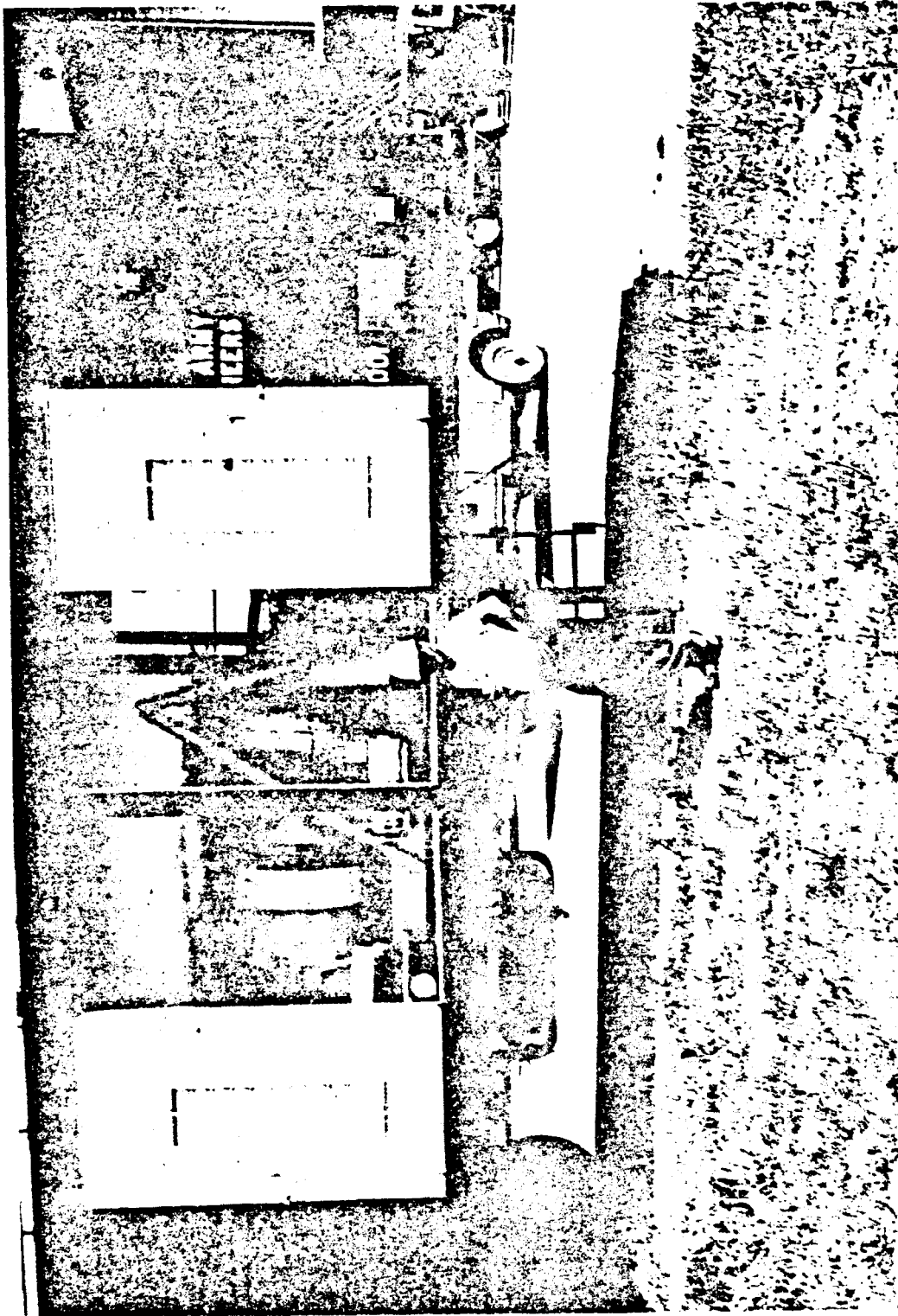Figure 3-3. Skid Mounted Gas Compressor

Figure 3-4. Gas Turbine-Generator

3.4 ECONOMICS

Table 3-1 below shows the major hardware cost elements for this type of power generation system. Specific numerical values for total system hardware costs are quite sensitive to actual site conditions, particularly the relative locations of the fuel source, the conversion equipment and the point at which the power generated is mixed into the mine power grid. Typically, total hardware costs might be **$850-900/KW** of installed capacity.

TABEL 3-1: SYSTEM COST ELEMENTS 800kW SATURN UNIT

Cost Element	% of Total Cost
Gas. Turbine-Generator[1]	
• Basic Unit	46
• Switchgear	7
• Remote Monitor/Instrumentation	5
Skid Mounted Gas Compressor	29
Transformer (4160/12000)	3
Fused Safety Switches	1
Pipeline (2 miles @ 6 inches)	7
Site Preparation	2
• Access **Roads**[2]	
• Site Leveling[2]	
• Protective Fence[3]	
Total	**100**

1. Unit is an 800KW unit produced by SOLAR Turbines International (California) Dual **(Liuqid/Gas)** Fuel operation is built into the system.

2. Based on **$45/hour** for bulldozer and **$15/hour** for operator.

3. Ten foot wire fence around a 250 x 250 ft. area with a ten foot access gate.

The cost of power generated by such systems can be estimated from the relation:

$$(3.1) \qquad G_C = \frac{C_C \times F_{CR}}{8.76\ (1-R_O)} + \frac{H_R \times F_C}{105} + OM$$

where:

G_C = Cost of generating power, **mills/kWh**

C_C = Equipment cost, **$/kW**

R_O = Turbine Outage rate, %

H_R = Incremental fuel consumption rate, **BTU/kWh**

F_C = Fuel costs, cents/10^6 BTU

OM = Operation/maintenance costs, mills/kWh

F_{cr} = Fixed charge rate, including insurance, depreciation and return to investor.

In this relation, at the Marianna No. 58 site, the second term on the right side of (3.1) goes to zero because the fuel cost factor, F_c, is borne by the mine degasification program budget. For the range of variables anticipated here the cost of turbine generated power is expected to be about 20 mills; a reduction of 20 to 25 mills in the present cost of commercially supplied power. This annual saving will grow as the price of commercially supplied power continues to escalate. A "levelized" value for this annual savings over the life[6] of the system is given by:

$$(3.2) \qquad P^*_{as} = P_{asi} \left[USCR \right] \sum_{n=1}^{n=12} \left(\frac{1 + r_e}{1 + i} \right)$$

where:

P^*_{as} = "levelized" value of the annual energy saving over the system life.

P_{asi} = initial value of the annual energy saving.

USCR = uniform series capital recovery factor; equal to

$$\left[\frac{i(1+i)^n}{(1+i)^n - 1} \right].$$

r_e = rate of escalation of the price of commercially supplied power.

i = current discount rate.

For the simplified case of $r_e = i = 12\%$, and P_{asi} = 25 mills, the corresponding value of P^*_{as} = 48.3 mills. For turbine generator power levels of 650 kW, 675 kW and 700 kW delivered to the mine power grid, the corresponding "levelized" annual dollar savings are $251,447, $261,118 and $270,788 respectively. In all three cases, and for an investment of $900/kW of installed capacity, the payback period is less than three years.

Westinghouse expects to start the accumulation of actual experimental field data on this type of system in the very near future. This data base will be used to further refine and improve the projected economics of this type of system.

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6. The useful lifetime of the saturn model 800 kW turbine-generator is normally taken to be twelve years.